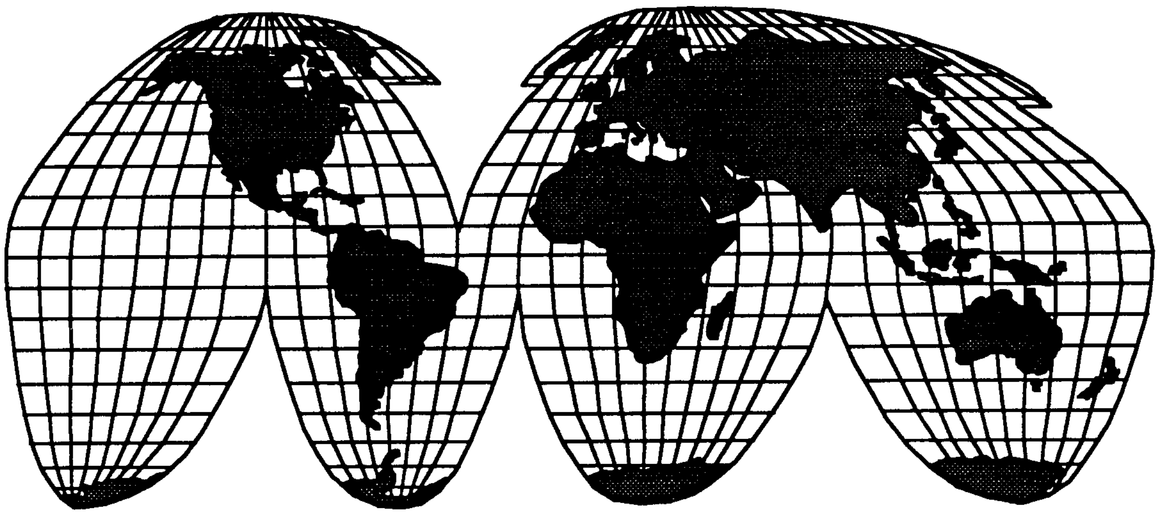
TRADOC Pamphlet 525-41

TOPOGRAPHIC SUPPORT FOR TERRAIN VISUALIZATION



OPERATIONS CONCEPT

1 APRIL 1997

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FOREWORD

Terrain visualization supports current and future national requirements for military forces. Upon notification of a possible operation, the commander needs immediate knowledge of the projected area of operations and of the area of interest. To provide that knowledge, the organization engineer officer conducts an engineer battlefield assessment (EBA) using powerful, technologically-advanced tools. Toward this end, digitized terrain data must be available over the entire area in all databases required by the several command and control systems, mission planning and rehearsal systems, and in models and simulations which allows rehearsal of potential courses of action. The terrain coverage must be in sufficient detail to support mission execution as well as planning and rehearsal processes. With this complete coverage, and with the power to determine the significance of the terrain to the mission, the commander has the means for terrain visualization and all users have a common image of the battlespace as their frame of reference.

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Headquarters, United States Army
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Fort Monroe, Virginia 23651-5000

1 April 1997

Military Operations

CONCEPT FOR TOPOGRAPHIC SUPPORT FOR TERRAIN VISUALIZATION

Summary. This concept serves as the basis for changes to topographic support doctrine, training, leader development, organizations, and materiel focused on soldiers (DRLOMS). This pamphlet describes how topographic operations develop "terrain visualization," and why the commander needs this key part of the battlefield visualization.

Applicability. This pamphlet applies to all U.S. Army Training and Doctrine Command (TRADOC) installations and activities that develop DTLOMS requirements.

Suggested improvements. The proponent of this pamphlet is the Deputy Chief of Staff for Combat Developments. Send comments and suggested improvements on DA Form 2028 (Recommended Changes to Publications and Blank Forms) through channels to Commander, TRADOC, ATTN: ATCD-BP, Fort Monroe, VA 23651-5000. Suggested improvements may also be submitted using DA Form 1045 (Army Ideas for Excellence Program (AIEP) Proposal).

Availability. This publication is also available on the TRADOC Homepage at http://www-tradoc. army.mil.

Contents

*This pamphlet supersedes TRADOC Pamphlet 525-41, 20 July 1984.

Chapter 1
Introduction

1-1. Purpose. To describe required U.S. Army topographic engineering capabilities to support forces in a force projection mission within a joint environment between 1996 and 2025.

1-2. References. Required publications are:

a. FM 5-100 (Engineer Operations).

b. FM 5-105 (Topographic Operations).

c. FM 5-33 (Terrain Analysis).

d. TRADOC Pamphlet 525-5 (Force XXI Operations).

e. TRADOC Pamphlet 525-70 (Battlefield Visualization Concept).

f. TRADOC Reg 11-16 (Development and Management of Operational Concepts).

1-3. Explanation of abbreviations. Abbreviations used in this pamphlet are explained in the glossary.

Chapter 2
Overview

2-1. Why this concept is needed.

a. Terrain visualization is a basic and fundamental leadership skill. A battle commander must understand how terrain influences every aspect of military operations. The great battle captains of history all had a powerful grasp of the importance of "good ground for battle." Historically, leaders walked the terrain where they would later fight. At Gettysburg, Pennsylvania on a hot July day, General Meade's staff engineer, Brigadier General Gouverneur K. Warren, in his mind's eye, saw the power of dominating terrain. Taking the advice of his engineer, General Meade anchored the shank of the Union "fish-hook" interior lines on Little Round Top, thus creating the conditions for a decisive victory. The situation was ironic. Where Jackson, Longstreet, and Lee were able to walk the terrain, they were often successful. Com-manders have always required a detailed awareness of the entire situation, to include the environment, the enemy, and the friendly situation. This total situational awareness is called battlefield visualization. Terrain visualization, then, is far from a new requirement. However, in the era of force projection, we must leverage every means available to provide battle commanders with this fundamental knowledge of terrain during planning, before operations commence. Information technology and digitization of the force provide a means to that end. Terrain visualization is a component of battlefield visualization. It portrays and allows a detailed understanding of the background upon which enemy and friendly forces and actions are displayed. Topography provides the "picture" whereby the user can visualize the terrain. Terrain visualization includes the subordinate elements of: data collection, database development and management, data analysis, data distribution, and data display. These elements include both new and changed tasks because of the new way of looking at the battlefield based on digital data. The elements are designed to provide the necessary visualization for the commander and the staff, and to control and manage a central terrain database.

b. As the Army moves toward terrain visualization in Force XXI, hard copy paper maps and products are giving way to a digital, information-based system. The information-based system provides digital maps and analyses which feed into the battle command systems directly, as well as indirectly through mission planning and rehearsal systems and simulations. We will design the topographic force to provide terrain information to the theater combatant command, corps, divisions, and brigades through a split-based operations mode. Future topographic equipment will be state-of-the-art commercial equipment and Army common hardware and software. This equipment will be organized into sets at the battalion, company, division, and detachment based on mission requirements for capabilities. The sets will be designed for split-based and fixed facilities and are significantly downsized from the current van-mounted sets in order to support rapid deployment, early entry operations. The sets produce and manage databases for the battle command systems, generate hasty maps, and build special visualization and analysis products. Specialized reconnaissance and survey equipment, built around Global Positioning Systems (GPS), digital video systems, and synthetic aperture radar supplement the general topographic sets. Paper map requirements may be met by users printing small size color maps from their battle command system, with flexible scaling and level of detail. Traditional size maps may be produced by the terrain detachment or company in limited quantities to supplement those available from the Defense Mapping Agency (DMA). Large quantities of paper maps may be printed by DMA or under contract. Terrain data may be developed for contingency operations on a mission-planning related timeline. In a crisis mode, it may be provided by the coordinated efforts of DMA, the Army's Rapid Response Team (ARRT), and field topographic units.

2-2. Paper maps. Maps have taken many forms over the centuries. Perhaps the most useful map for the military has been the topographic map. Topographic maps can be described as general-purpose maps since they can be used and interpreted in many different ways. Another map that has made recent gains in the military is the "thematic" map. Each thematic map depicts only one feature (i.e., soil type, forested areas, or road networks). Such maps can express either qualitative or quantitative data. The quantitative data can be described mathematically, therefore lending itself to computerization. Qualitative data may also be computerized.

2-3. Limitations. Until recently, maps consisted solely of a geographical representation of the earth's surface on a sheet of paper or acetate. Information was represented as points, lines, or areas. The basic features were represented with colors, different symbols, or text that was explained in the legend. The amount of data that can be depicted on a paper map and recorded in accompanying notes is very limited; however, until recently, this has been the only database available. Several factors influence the collection, coding, and use of information incorporated into a hard-copy graphic representation. First, the volume of the data must be greatly reduced and classified into various categories. Much information is filtered out and lost. Secondly, maps must be drawn with great precision and accuracy, and the presentation of even complex themes must be clear. Thirdly, where large volumes of data must be depicted at large scales, several map sheets are required. Frequently, the area of interest is at the juncture of two or more map sheets. Fourthly, once the data has been placed on the map sheet, it is expensive and difficult to extract it in order to combine the information with other data. Often, there are differences in map scales used by higher, adjacent, or lower units. With a printed map, passing overlay information across different scales is difficult. Finally, a printed map is static. The quantification of the data is extremely difficult without the collection of additional information for the problem at hand. The process of terrain visualization is highly dependent upon joint and combined digitized terrain processing means and uninterruptable electronic transfer of large amounts of information.

2-4. Pace. Paper maps cannot keep pace with rapidly-changing situations. The collection, creation, and printing of paper maps are costly and time consuming. Manual extraction and analysis of thematic information are also prohibitively expensive. At one time, maps were thought to have a useful life of 5 to 20 years; however, on the modern day battlefield, the data can and may change from hour to hour. Timely map updates are not possible using the manual method of map making. The time-honored practice of creating acetate overlays in grease pencil is rapidly becoming an anachronism.

2-5. Cartographic technology. The hand-drawn map is a "snapshot in time" of the earth as seen through the various data filters of a given surveyor, cartographer, and analyst. Remote sensors and computer software have made it possible to see change more readily. The sensors do not store their data in the familiar map symbols and codes, but as two-dimensional cells called pixels. Special tools and skills are needed by the cartographers to turn the numbers in the pixels into meaningful images and information. Though the remote sensors can provide valuable real-time data to the commanders, it is essential that the data be linked to ground truth. Therefore, a limited amount of traditional surveying must be accomplished in order to facilitate the calibration and validation of the data and to assure its proper spatial interpretation.

2-6. Engineer topographic mission. Engineers have the responsibility to advise commanders on the effective use of the terrain. The digitized, information-enhanced Force XXI Army may require immense databases, of which the terrain information database is one part. The engineer topographic mission includes providing and sustaining this database. Instead of the now-familiar map supply as part of a "stovepipe" mapping, charting, and geodesy interface with DMA, this concept is a new way of presenting and describing topographic information. Army topographic units develop detailed information of the ground, analyze the military aspects of this ground, and provide this knowledge to the user. The necessary elements are data collection, database development and management, data analysis, data distribution, and data display.

Chapter 3
Concept

3-1. General. Topographic engineering responsibility in supporting forces requires the capability to rapidly build and manage a dynamically growing geo-spatial database, exploit that database for production of products and tactical decision aids (TDA), produce products, and distribute updated products and data to support commanders and battlefield operating systems. Topographic engineering support provides operational and tactically oriented terrain analyses, standard and substitute/provisional map products, and survey data to combat, combat support, and combat service support forces in all phases of operations throughout the theater. The DMA is responsible for producing standard mapping, charting, and geodesy (MC&G) products and databases. Army topographic engineering support builds upon that DMA support in four ways:

a. Topographic engineer units provide immediate support to commanders to help in visualizing the terrain within the contingency area. To provide this support topographic engineer units exploit all available information sources, including DMA standard maps, charts, and databases, host nation maps and charts, imagery, terrain analysis studies, non-DMA existing digital data, survey databases, and all-source intelligence data, quickly to provide MC&G support focused on the commander's immediate need to visualize the terrain within the battlespace. This immediate support may include providing copies of existing maps or charts, verbal information, hastily produced products, or reproduction of existing products.

b. Topographic engineer units update and add value to standard DMA products and databases, build provisional databases as required where data layers do not exist or are inadequate, and manage the dynamically growing geo-spatial database for a contingency area. Topographic engineers transform standard DMA databases and products, and other nonstandard products, including those produced by other countries, into tailored support focused by the commander's need to visualize and exploit the terrain. Prioritization of effort throughout is driven by the commander's intent and the mission, enemy, terrain, troops, and time available (METT-T) analysis. Topo-graphic engineer units rapidly generate provisional geo-spatial data from any available source, merge this locally acquired/developed data with standard DMA products and databases, and manage this ever growing database. They assure all products/data are on a common coordinate system, consistent with other data, and immediately available for exploitation. Topo-graphic engineer support includes, but is not limited to, performing terrain analysis for the Intelligence Preparation of the Battlespace (IPB) process, the EBA process, and updating existing maps and charts with imagery-based analysis or other forms of intelligence. Topographic engineer units also establish and record geodetic survey control in theater.

c. Throughout the operation, topographic engineer units act as the terrain information conduit between theater and mapping agencies, while managing the dynamic, growing geo-spatial database. Some terrain elements, such as cultural features, may change rapidly once operations begin. Other terrain elements remain consistent and unaltered by operations. Knowledge of the terrain may rapidly increase either as a result of focused study or actual occupation. Topographic engineers must manage this dynamic database. They must maintain qualitative information concerning coverage, resolution, standards, source, currency, accuracy, uncertainty, and limitations of all data elements. They must also assure that older, superseded data is quickly and consistently removed from the database. This may help in ensuring that users are provided the most up-to-date data available. Data management is critical to assure products produced by exploiting the database are as accurate and reliable as possible. This phase of support includes passing provisional or acquired data back to DMA for possible DMA exploitation as DMA updates, maintains, and rapidly disseminates the updated databases and products.

d. Split-based topographic operations are inevitable given the growth of communications technologies, evolution of digital mapping capabilities, and the transportation resource constraints of a CONUS-based force. Topographic units may deploy key topographic support capabilities in small teams, backed by a strong base. The forward-deployed element may link to the base electronically. Topographic units may develop and deliver terrain visualization support in the form of both data and products through the combined efforts of the forward-deployed and the base elements.

3-2. Contingency operations. Commanders require topographic support in theater on a timely basis for that support to be useful. Topographic support units may meet this timeliness requirement by deploying with the supported force, sending the support via communication links, or some combination of the two. The number of topographic support elements deploying to the theater may vary with the suitability and availability of adequate MC&G products, geo-spatial database, and with the communication links available for transmitting support from outside the theater.

3-3. Topographic support during force projection operations. Army topographic engineers must be able to support joint and combined force projection operations. Topographic engineer units assure that timely, accurate, and sufficient knowledge of the battlespace terrain is provided to each commander throughout all phases of operations. They assure comprehensive products are available to help the commander in planning for and executing operations.

a. All aspects of military operations require topographic support. Commanders require accurate and timely topographic information for planning, decision-making, and executing operations. Topo-graphic engineer operations <u>must</u> provide the commander with this support as commanders must quickly evaluate military aspects of terrain, e.g., observation/fields of fire, cover and concealment, obstacles, key terrain, and avenues of approach (OCOKA). Topographic products must give the commander an effective means to evaluate the terrain within the assigned battlespace and its impact on every battlefield operating system.

b. Standard DMA tactical scale maps and databases may be available for only a small percentage of the Earth's surface for many years to come. Even when available, standard DMA data may require maintenance or updating for most contingency operations. That means that deployments to theaters with little standard DMA coverage will require significantly more topographic engineering support. Topographic units will be allocated based on the work effort required and not based upon the notion that specific units support specific sized deployments.

c. The only data that is available for every contingency is imagery from classified and commercial sources. To meet the mapping and terrain data requirements needed to carry out the force projection mission, the Army must have the capabilities for rapid production of image-based topographic products, building and management of a dynamically growing geo-spatial database that key systems can use, exploiting that database to develop products and TDA, and rapid distribution of updated products and data to support commanders and operations. This recognizes the topographic engineers' responsibility to provide timely, tailored, topographic products responsive to Army commanders in a force projection force by either augmenting standard DMA support or providing substitutes when standard DMA support is not available.

d. The exploitation of terrain is a key element of most battlefield operating systems. Topographic units provide digitized terrain data and exploit databases for the specific needs of these battlefield operating system "customers." This exploitation capability may give every key node a terrain analysis capability formerly available only at the divisional staff level.

e. Combat-oriented topographic products are prepared from existing databases. Historically, these products have been furnished graphically (as maps, imagery, image maps, charts, and overlays), digitally (as tapes and disks of digital elevation, feature data, and multispectral imagery), textually (as gazetteers, trig lists, and terrain studies), and as oral presentations or briefings.

f. Normally, standard topographic products used in support of combat operations are prepared by the DMA or by host nations through international agreements negotiated by the DMA. Army topographic engineer units supplement and enhance the DMA's efforts. They give the commander specific tailored products reflecting the current state of the terrain, and the commander's METT-T analysis.

g. Weapons, mission planning, rehearsal, modeling and simulations, and command and control systems also require topographic products and databases. Generally, these are required in specific formats. Weapon systems require ground or aerial control data for geodetic positioning, azimuth, and targeting. Mission planning and rehearsal systems require digital data of specific mission areas to provide improved high resolution simulation. Command and control systems require digital data to support tactical planning, other planning functions, and execution functions. Satellite image maps may provide the only accurate digital map for many areas of the world until appropriate data sets can be produced. While imagery and image maps provide only limited functionality, they may be the only map background available for those key systems. Army topographic engineer units must produce image based map backgrounds and other select products using imagery pending availability of standard data.

h. Combat support and combat service support units require accurate topographic products for planning and execution of operations. Commonly acknowledged missions requiring topographic engineering support include identifying lines of communications, determining movement rates, citing communication systems, and positioning critical command and control and logistics activities to increase effectiveness and reduce vulnerability.

3-4. Future operational capabilities.

a. Joint level.

(1) Unified commands. The geographical Commanders in Chief (CINC) are responsible for all joint operations within their designated areas. Their MC&G officer serves as a single focus for all MC&G support within the command. Unified commands evaluate missions, objectives, force allocations, and system deployments in order to identify through the MC&G area requirements process MC&G products and service requirements essential to mission success. They coordinate MC&G support to components, joint task forces (JTF), direct reporting units, supporting foreign forces, and command headquarters. MC&G support may be from DMA, organic capabilities, other Department of Defense (DOD) units, other federal agencies, or foreign countries.

(2) JTF. Identify MC&G area requirements to support operations orders (OPORD). Collect, review, and recommend validation of MC&G area requirements from component commands. Coordinate MC&G support within the task force.

(3) Army Force (ARFOR) commander. Serves as the single focus for all MC&G support for Army forces in the JTF. Responsible for directing, supervising, and coordinating all MC&G issues that impact the command. Be prepared to, on order, assume responsibility to coordinate all MC&G support required within the JTF.

(4) DMA. DMA has overall responsibility for MC&G, including topographic engineering, throughout the DOD. DMA is responsible for producing standard maps, charts, and digital data products to support the Army at all levels and for topographic resupply of standard products to theater level. DMA also produces standard digital terrain databases tailored by Army agencies or topographic units to support command and control, weapons, mission planning, rehearsal, and combat support systems.

b. Army service level.

(1) Topographic engineer units. Topographic engineers provide timely, accurate knowledge of the battlespace and terrain visualization to commanders at all echelons throughout the operational continuum. They are allocated to the ARFOR component of the JTF in strength sufficient to provide the required support within

the time required. Topographic engineer responsibilities for supporting the Army's force projection mission are: rapid production of image-based topographic products; building and management of the dynamically growing geo-spatial database; exploiting the geo-spatial database for production of products and TDA; and rapid distribution of updated products and data.

(2) Army logistic units. Map distribution (storage, requisition processing, and issue) of unclassified standard MC&G products is through logistic channels. Classified products are distributed through intelligence channels. Specialized product distribution is handled between the topographic unit and the requesters.

(3) Communications systems. Command and control systems that rely on digital terrain MC&G data must receive that data in accordance with (IAW) procedures established by signal elements.

c. Army engineer labs**.**

(1) Topographic Engineering Center (TEC). The TEC provides direct support or general support to theater topographic engineer assets. They exploit their ongoing research and development in the topographic sciences, and provide operational support or unique tailored support that topographic units cannot provide.

(2) U.S. Army Corps of Engineer Laboratories, Waterways Experiment Station (WES), Construction Engineering Research Laboratory (CERL), and Cold Regions Research and Engineering Laboratory (CRREL). These laboratories can provide direct or general support to theater topographic engineer assets. They also exploit their ongoing research and development in the topographic or related sciences, to provide operational support or unique tailored support that topographic units cannot provide.

Chapter 4
Implications

4-1. General. Engineers are responsible for providing the means to achieve terrain visualization. Terrain visualization impacts <u>all</u> battlefield operating systems. By combining the <u>science</u> of terrain visualization with other military arts and sciences, the leader gets the picture of the battlefield and an understanding of the factors that may affect decision-making. Of all the implications, developing leaders who understand the importance of "reading the terrain" and are comfortable with the means, is the single biggest challenge.

4-2. Doctrine.

a. The most significant doctrinal change is the revolutionary change from product-based to information-based terrain visualization. The user will now have the required information at his/her fingertips and can call on it when needed. Users can conduct limited "what if?" analyses right at their operational work stations.

b. Current doctrine and tactics, techniques, and procedures (TTP) for production, distribution, and requesting paper maps may become obsolete as the digital command and control systems are fielded. Organizational TTP for all battlefield operating systems may include "do-it-yourself" printing of custom maps for specific missions and functions.

c. Specific doctrine for managing and safeguarding field databases may be developed, along with supporting TTP for all distributed battlefield terrain databases. Procedures providing quality control and cross-checking of field-collected data may assure database integrity.

d. Topographic support planning for a contingency operation may be based on the data production timelines. Doctrine may include the evolving roles of the DMA, the Army Corps of Engineers Laboratories, and Army field topographic units.

e. Future land force operations may generate some requirements for hard copy paper maps and special products, especially at the lower tactical levels of execution. This concept acknowledges these requirements.

4-3. Training.

a. Training, supplemented by new equipment training (NET) courses may encompass new areas as digitization is brought into the force. Professional development courses may provide the majority of the transition training and may be keyed to a timeline supporting the first, fully-digitized unit. Affected courses may include officer education system (OES), noncommissioned officer education system (NCOES), and senior service colleges (SSC).

b. Soldiers may continue to train on map reading and land navigation. Training must also concentrate on understanding image maps and three-dimensional terrain views. Future training may also include using heads-up displayed three-dimensional maps as navigational and operational aids. Fielding modernized equipment IAW WARNET XXI will benefit from digital connectivity and other technological advances which make embedding improved training capabilities into equipment feasible. This training may receive particular emphasis in basic leadership courses.

c. Leaders may be taught to use elementary terrain analysis on their battle command systems to support normal field operations such as route selection and position citing, in the officer basic courses and noncommissioned officer (NCO) basic and advanced courses.

d. Battle staff personnel may be trained to conduct their own terrain analysis, supporting their missions, using the capabilities built into the battle command systems. This training may be incorporated into their branch advanced course and Battle Staff NCO Course.

e. All engineer officers will receive extensive terrain visualization training in their basic and advanced courses.

(1) Training for topographers (MOS 81 series) will be significantly different. An extremely high level of computer competence, including operating system proficiency, is required for productivity.

(2) Topographers will spend more training time learning expert-level terrain analysis. More difficult analytic tools and more statistical inference, based on data reliability and age of data may be taught. Students may also learn how to include changes based on weather and the effects of military operations.

(3) Training for topographic engineers may be a combination of commercial contract and Army school training. Since the major software is commercial off-the-shelf (COTS), commercial courses are the most cost-effective training technique. Army schools may teach detailed analysis using the software, as well as field database operations, reconnaissance, and survey.

4-4. Leader development.

a. Leaders will be taught the advantages and disadvantages of visualization techniques available within the battle command systems. Schools will provide extensive hands-on practice, embedded in other training, to enhance this understanding.

b. Leaders will also be trained to recognize limitations of analysis when based on limited or outdated data. Course of action assessment may include the uncertainty associated with terrain analysis.

c. In order to develop leader confidence and skill using a less-than-perfect picture of the ground, combat training centers may include scenarios with incomplete and outdated terrain data.

4-5. Organization.

a. The topographic organization may change to the one described in chapter 3 as the supported force becomes digitized.

b. Reconnaissance and survey teams may be reorganized to take full advantage of precise GPS survey and digital reconnaissance tools. Engineer reconnaissance capability may be incorporated into engineer battalions based on insights from the experimental force (EXFOR).

4-6. Materiel.

a. Specific topographic systems requirements for terrain visualization have been identified in the Topographic Engineer Master Plan and the Terrain Visualization Master Plan. A concept document generally describes materiel requirements only in broad terms, without specifying performance standards. Both master plans identify specific materiel systems. We wrote the Topographic Engineer Master Plan and the Terrain Visualization Master Plan <u>before</u> articulating this concept. We acknowledge getting the requirements determination process out of sequence, but after careful review, have determined that the separate documents are fully compatible and complementary. This concept validates the master plans which identified materiel systems. There are no new requirements as a result of this concept.

b. The critical materiel challenge may be large scale database management of the various command and control systems of which the terrain visualization is a part.

4-7. Soldier implications. Implementation of this concept may require <u>no</u> additional personal or organizational clothing and equipment and will <u>not</u> increase the soldier's burden.

Glossary

ARFOR	Army force
ARRT	Army's Rapid Response Team
CERL	Construction Engineering Research Laboratory
CINC	Commander in Chief
COTS	commercial off-the-shelf
CRREL	Cold Regions Research and Engineering Laboratory
DMA	Defense Mapping Agency
DTLOMS	doctrine, training, leader development, materiel, and soldiers
DOD	Department of Defense
EBA	engineer battlefield assessment
EXFOR	experimental force
GPS	Global Positioning System
IAW	in accordance with
IPB	Intelligence Preparation of the Battlespace
JTF	joint task force
MC&G	mapping, charting, and geodesy
METT-T	mission, enemy, terrain, troops, and time available
MOS	military occupational specialty

NCO	noncommissioned officer
NCOES	noncommissioned officer education system
NET	new equipment training
OES	officer education system
OPORD	operations order
SSC	senior service colleges
TDA	tactical decision aids
TEC	Topographic Engineering Center
TTP	tactics, techniques, and procedures
WES	Waterways Experiment Station

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